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Commentary: Giuseppe Campani (1635-1715 Rome, Italy): the first use of a microscope in medicine and surgery

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Significance of the Work: Please include a brief statement summarizing the significance of the work and in particular how it differs from and advances existing literature.	This historical article highlights the legacy of Giuseppe Campani, microscopes and telescopes maker of note in the 600' in Rome, Italy. Thanks to his unique art in lens grinding he provided telescopes and microscopes for scientists as Galileo Galilei and Anton van Leeuwenhoek during the Scientific Revolution. In the Vatican Library we had access to Campani's letter to Pope Innocent XI, in which he describes the application of the microscope in a medical setting for the first time in the history of medicine. While the historical importance of the lithography accompanying the letter was previously recognised, to our knowledge, this is the first record where his letter has been translated from Latin to English, unveiling the philosophy and the scientific concepts underlying Campani's microscopes. In this manuscript we provide with the full English translation of his letter. Moreover, we highlight the modern analysis of his lenses to give emphasis to his knowledge in the theory of optics and his sensibility to the needs of the scientists in line with Francis Bacon's philosophy.
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Giuseppe Campani (1635-1715 Rome, Italy): the First Use of a Microscope in Medicine and Surgery

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Abstract

Giuseppe Campani (1635-1715) was a polymath in Rome, Italy, during the Scientific Revolution in the XVIIth Century. In particular, he forged the screw barrel microscope and was manufacturing his own lenses for microscopes and telescopes. He mastered the art of lens grinding. Those lenses have been analyzed with modern methods and turned out to be of extremely good quality, shining light on the fact that Giuseppe Campani mastered the theories of optics. Moreover, in a letter that Giuseppe Campani sent to Pope Innocent XI, he clearly described the use of a microscope for the examination of wounds of legs. This letter dates back to 15 August 1686 and is the first evidence of the use of microscopes to analyze wounds, sores, and anatomical specimens in medical and surgical settings. MG Yasargil previously showed the lithography accompanying this letter and was the first to recognize its great importance. We accessed this original letter in the Vatican Library and for the first time we have translated it from Latin to English in order to unveil its significance in the context of the Scientific Revolution and the history of medicine and surgery.

Keywords: microscope, optical instruments, lenses, Giuseppe Campani
Short Title: Giuseppe Campani's legacy to neurosurgery

THE SCIENTIFIC REVOLUTION

The Scientific Revolution, a term coined by Alexandre Koyre in the 20th Century, took place in Europe at the end of the Renaissance and represented the transition to modern science. The Scientific revolution announced a drastic methodological and philosophical change in physics, mathematics, biology, and astronomy.

In contrast to the deductive approach of Aristotelian origin, an inductive philosophical approach attempting to observe nature with an open mind became predominant in science. Francis Bacon (1561-1626), in the *Novum Organum*, stated that man is "the minister and interpreter of nature" and that "***effects are produced by themes of instruments and helps.***"[1-4]

While the publication in 1543 of Nicolaus Copernicus's *De Revolutionibus orbium coelestium* (On the revolutions of heavenly spheres) marks the beginning of this major scientific shift[1], Isaac Newton's *Principia* in 1687 on the laws of motion and universal gravitation marks its completion[2].

This change in attitude, supported by Francis Bacon and other eminent personalities such as Galileo Galilei (1564-1642), contributed to the constitution of scientific societies such as the Royal Society[5].

GIUSEPPE CAMPANI (1635-1715)

Giuseppe Campani was a polymath who mastered the theories of optics. He was born in 1635 in Castel San Felice, Italy, during the Scientific Revolution. He was known for the development of the pendulum clock. In 1650, he moved to Rome to join his 2 elder brothers and probably studied in Collegio Romano, a pontifical university founded by Saint Ignatius of Loyola, although little is known about his life before 1660.

Two of his 3 daughters died prematurely. The surviving daughter played an important role in the construction of lenses for his microscopes and telescopes and was the only custodian of his secrets on lens grinding[6]. In fact, Campani worked in private behind closed doors to protect his inventions and techniques.

In 1656, Pope Alexander VII noticed his new invention, the silent night clock. This marked his rise in fame for his lenses and optical instruments. It is thought that he learned the basics of optical polishing at the shop of Eustachio Divini (1610-1685), with whom he had open rivalry in the years to follow[6].

In 1664, Giuseppe Campani published a description of telescopes with very long focal lengths, one of which he used to observe Saturn, revealing his invention of a lathe for polishing and grinding lenses. His invention of a compound eyepiece with 3 equally spaced lenses of the same focal length remained the standard for nearly 1 centuries when it was replaced by spyglasses.

Campani quickly became known as Europe's finest telescope and microscope maker. Giuseppe Campani died in Rome at the age of 80.

Giuseppe Campani's microscopes

Giuseppe Campani is claimed to have invented the screw barrel system for adjusting the focus in microscopes and telescopes[8]. Prior to this, mechanisms for focusing consisted only of gliding tubes and were far less precise.

In a letter sent to Pope Innocent XI, nowadays archived in the Vatican Library (Figure 1), Giuseppe Campani described his microscope and its use for the examination of wounds of legs. This letter dates back to 15 August 1686 and is the first evidence of the use of microscopes in the history of medicine and surgery. This letter also contains an illustration of the microscope's particular usage. Following is the English translation from Latin:

"*This man, Your Eminence, added a microscope to his ingenious discoveries, the maximum height of which is about 5 inches and the minimum less than 3 inches and that can be built with even smaller dimensions. It surpasses all others made up to now, even though there have been many lenses, for its ability to magnify objects, for a greater field of vision, its clarity, and manner of use.* ***It magnifies objects*** *more than other microscopes, even 6 or 7 times more.* ***It expands the field of vision*** *more than its own diameter and more than its own height.* ***It maintains admirable clarity*** *(whereas usually in others it diminishes or is lost, due to excessive magnification of the objects), also of the extremities of the objects. Its use, in turn, is singular, since* ***the base, which serves as the support for objects being observed, is predisposed for the microscope to view always with optimal lighting and at any angle.***

This microscope is useful for observing all types of objects: those very transparent and those opaque, solids and fluids; they are enclosed between 2 pieces of glass, in which even microscopic organisms can be stored for several days, thus making it possible that any part of the organisms can be easily observed in a detailed manner. Therefore, in diaphanous objects one

can much more easily observe movement of the nerves, lymph and juices, as well as the microscopic organisms in the semen of any living being; thanks to the microscope, Leeuwenhoek has already discovered the spherical drops. ***In addition, on removal of the base, this microscope is also useful to examine the wounds and sores of living beings, and all the other details, even the very smallest, of any anatomical part of the bodies of the subjects.***

Published by Schelstrateno, prefect of the Vatican Library in a letter signed in Rome 15 June 1686.
(Referring to Figure 2 - accompanying the letter) *We follow here with a table in which No. 1 is a picture of this microscope: it demonstrates what the use of this microscope has in common with others; No. 2 shows the particular use of this microscope, for observing transparent bodies; No. 3 shows its use for observing wounds and scars".* Letter translated and published with permission.

The lithography (Figure 2) accompanying the letter being the first manifestation of the invention of the screw-barrel type optical viewing system was previously shown and recognized to be of great importance by MG Yasargil[9,10]. The lithography shows the first ever microscopic intervention in medicine and surgery.

It is of great interest that Giuseppe Campani refers in his letter to Antonie van Leeuwenhoek (1632-1723), Dutch scientist, considered the "father of microbiology" being the first to have described microorganisms -"animacules"- under the microscope[11]. Van Leeuwenhoek also developed a great interest in lens making for microscopes and had a great familiarity with glass processing.

Campani's microscopes were produced in a compound construction to make the screw barrel focus possible. They usually consisted of 2 tubes that could be screwed into each other. This system became archetype for the Wilson screw barrel and other similar systems for adjusting the focus. Later he also constructed other microscopes with a double focusing arrangement, 1 for the regulation of the distance between the object lens and the object, the other for the distance between ocular lens and object lens[12].

Campani's microscopes were designed for the use of natural light, although there had been attachments for illuminating systems[13], formed by a candle and a mirror as shown in his lithography (Figure 2). With natural light the microscopes could be utilized to examine either opaque objects either transparent objects with a clip device and a transmitted light[14]. Some constructions were placed on a brass stand with a retainer to fixate objects probably made of ivory or bone [15-17].

Optical Workshop Equipment of Giuseppe Campani

In 1747, 3 decades after Campani's death, Pope Benedict XIV purchased his optical workshop equipment from his daughter and donated it to the Institute of the Sciences in the University of Bologna. Ercole Lelli (1702-1766), anatomist and painter of considerable note in Bologna, trained by Campani's daughter on how to operate the equipment, was appointed to supervise the collection. Due to his untimely death, his study of Campani's methods was not published and his notes have not been found. Meanwhile, August Denis Fougeroux de Bondaroy (1732-1789) was assigned by the Académie Royale des Sciences to study Campani's workshop equipment, on which he wrote and presented a report in 1764 that was included in the Mémoires of the Académie. In his report, he noted that there were different elements that contributed to the perfection of the lenses[18].

Campani is believed to have used Venetian glass, which plays an important role in lens quality together with his developed grinding techniques and detailed workmanship. Glass was produced by high temperature melting of soda, lime, and silica components. Soda was obtained from algae that had dried and burned to fine ashes. The lime and silica were obtained from the pebbles of the river Ticino by the process of calcination, ie high temperature heating and crushing to powder. Despite its few impurities and air bubbles, Campani's lenses (Figure 3) seemed to be clearer, smoother, and more durable than those produced in France at that time. According to de Bondaroy, the secret of success of Campani lies in the different pattern of metal moulds of increasing degrees of fineness he gradually used to convert the glass into a lens. He used his own lathe to shape the moulds, which was not unique to Campani, but he had the

greatest accuracy in adjusting the length of the tool. To polish the lens, which was the most demanding part that risked deforming the lens itself, he used paper that he probably produced on his own for this purpose. To attach it to the pattern he used liquid gum, limiting the degree of surface inequality, and chose days of constant temperature to complete the polishing [18].

Modern Analysis of Campani's Lenses

According to Molesini's analysis of Campani lenses, they are of excellent quality, spherical shape, "with maximum departure from best fitting sphere of the order of a small fraction of a wavelength" [17]. The telescope that was examined had significant complementary astigmatisms on the 2 surfaces, resulting in a transmission without astigmatism. Furthermore, the lens seems to have undergone plastic deformation, due to constrained mounting. Although modern standards recommend a standard thickness of 1/10 of the diameter, Campani produced very thin lenses (1/20 to 1/30) with excellent surface shape leading us to believe that he used very gentle grinding and polishing techniques. All his lenses were signed and had marks of stains and scratches, probably a result of subsurface microfractures that caused detachment of glass chips (Figure 3). An investigation of the optical transmittance showed that the glass displayed the same features as window glass. Compared to modern lenses, the overall transmittance was lower, but still comparable to modern sheet glass. The resolution gets very close to the diffraction limit and chromatic aberration is minimal but air turbulences reduce the actual resolution of the lens.

Ludwig Otto (1851-1935) examined 2 microscopes made by Giuseppe Campani at the Optical Museum of the Carl-Zeiss-foundation in Jena, Germany. His comments on the lenses of the first microscope also admire the fact that hardly any astigmatism is detectable, but they show a bit of spherical undercorrection and distortion of 6%. The second microscope he investigated was in worse shape than the first apart from the fact that 1 ocular lens was missing, the objective lens showed bubbles with scratches on its surface. The remaining ocular lens showed no scratches or bubbles but the glass was a little discolored [19].

Nevertheless, Campani reached perfection for that time in constructing his lenses, microscopes and telescopes, which ultimately could only be surpassed by the construction of meter-class telescopes according to the "Fried's" parameter that indicates the critical size above which the resolution is limited by the atmosphere and no longer by the lenses [20].

CONCLUSION

Giuseppe Campani made an outstanding contribution to the history of neurosurgery providing the first evidence of the use of a microscope in anatomical, medical, and surgical settings. In the 1600s Campani already applied to the construction of his microscopes the same concepts which are the fundamentals to modern microneurosurgery, namely focus, magnification, and illumination. Modern analysis of his microscopes unveils Campani's willingness to perfection in producing high quality instruments at the service of science during the Scientific Revolution and beyond.

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FIGURE LEGENDS

FIGURE 1. A and B. Original letter in Latin that Giuseppe Campani sent to Pope Innocent XI on 15th August 1966 to describe the characteristics of his screw barrel microscope and its utility in scientific and anatomical settings. Focus, magnification, and illumination, which are fundamental concepts in modern microneurosurgery, are illustrated by Giuseppe Campani. This letter is currently archived in the Vatican Apostolic Library, Vatican City.

Figure 2. Lithography accompanying the letter in Figure 1, showing the microscope and its use for observing transparent bodies as well as wounds, scars, and human anatomical specimens. Of note, the light of a candle and a mirror are used to illuminate the field. This lithography represents the first documentation in the medical literature of the use of a microscope.

Figure 3. Campani's lens for a telescope (1665). Giuseppe Campani produced very thin lenses with an excellent surface and transmittance obtained by his gentle grinding and polishing technique. All his lenses were signed. This lens is dedicated to Ferdinando II de'Medici (1610-1670), Grand Duke of Tuscany. It was built for a 10-tube telescope that measured 11 meters in length when fully extended. With permission from Museo Galileo, Istituto e Museo di Storia della Scienza, Florence, Italy.

compoſitionem inter ſe connexa, oſtendent geometricam Problematis conſtructionem. Quamvis & aliis innumeris modis eadem concluſio ex datis poſſit elici. Quin imo *Autor* noſter his & ſimilibus innixus principiis, *ſtellarum in cælo* GENESIN a priori demonſtrandam aggreſſus (rem plane incognitam in philoſophia) quamlibet *ſtellam*, novam ac diverſam *Infinitis* comprehenſionem interpretatur. Eritque *quadrare circulum* hoc quidem ſenſu, nihil aliud, quam EX DATA LINEA conſtruere MUNDUM, DIVINÆ MENTI ANALOGUM; ſive geometrice exhibere productum infinitum omnium numerorum, in naturali ſerie 1 in 2 in 3 in 4 in 5 in 6 in 7 &c; hoc eſt, omnes Transpoſitiones, Generationes ac Conjugationes rerum, quæ per naturam fieri poſſunt, univerſali quadam Idea includere. Quod equidem quantis ac quam immenſis difficultatibus ſit involutum, cuivis Philoſophiæ initiato perſpectum eſt. Nemo autem majori voluptate vel veneratione hæc myſteria proſequi poterit, quam qui geometriæ peritus per varias ambages in Tetragoniſmo inveniendo ſeſe jam excruciaverit. Omnes enim aliorum in hoc genere conatus tum facilitate ſuperat, tum irrationales illas diſtractiones ex infinitis diſſimilibus congeſtas æque diſſipat hæc nova INFINITORUM SIMILIUM METHODUS, quam ipſius clariſſimi *Autoris* verbis perquam dilucide deſcriptam, brevi in Actis noſtris exhibituri ſumus.

DESCRIPTIO NOVI MICROSCOPII, AUTORE DN. Josepho Campano, ejusque uſus.

A Dn. Schelſtrateno, Vaticanæ Bibliothecæ Præfecto, in literis d. 15 Junii a. 1686 Romæ exaratis, communicata.

Adjunxit præſtantiſſimo hic Vir ingenioſis inventis ſuis microſcopium aliquod, cujus altitudo maxima ad quinque, minima infra tres pollices extenditur, quodq; multo adhuc brevius confici poteſt. Præſtat hoc omnibus aliis in hunc uſq; diem conſtructis, quamvis etiam multis lentibus conſtent, objectorum ampliatione, campi majore extenſione, claritate ac uſu. Auget enim objecta magis ac microſcopia alia quæcunque, etiam ſexies vel ſepties majora. Expandit campum majorem ſua ipſius diametro, ampliusq; ac ſua eſt altitudo. Mire conſervat claritatem ſuam (nimia objectorum ampliatione alias imminui perdive ſolitam) etiam in ipſis objectorum extremitatibus. Uſus

porro

porro eſt ſingularis; cum baſis objectum microſcopio ſubjiciens cuivis inclinationi, cum commoda ſemper luminis receptione, inſerviat. Conducit hoc microſcopium obſervandis omnium generum objectis, pellucidis, opacis, ſolidis, fluidis: hæc vero duobus vitris includit, in qua cuſtodia & animalcula per aliquot dies ita aſſervari poſſunt, ut facillimo negotio quæcunque animalculi pars exacte repræſentetur. Unde in diaphanis motus nervorum, humorum & chyli; ut & animalcula in ſemine quorumvis viventium longe facilius hic obſervantur, atque ope microſcopii guttæ ſphæricæ a Dn. Levvenhoek jam inventæ. Adde quod & baſi a microſcopio hoc remota, idem inſerviat inſpiciendis vulneribus & plagis viventium, omnibusque aliis vel minimis particulis cujuscunque membri corporum anatomiæ ſubjectorum.

TAB. X. Subjicimus tabulam, in qua n. 1 ipſius microſcopii figura apparet, qua ipſius uſus cum cæteris microſcopiis communis exhibetur. 2 habetur ejus microſcopii uſus ſingularis ad intuendum corpora transparentia. 3. ejus uſus ad conſpicienda vulnera & cicatrices.

LIBRI NOVI.

ISaaci Voſſii Obſervationum ad Pomponium Melam Appendix &c. Londini apud Rob. Scot. 1686, in 4.

Miſcellanea; in quibus continentur, Præmonitio ad Lectorem de infantum communione apud Græcos: Defenſio libri de Græcæ Eccleſiæ ſtatu: Brevis narratio de D. Cyrillo Lucario Patriarcha CPtano &c. Auth. Th. Smith. Londini 1686, in 8

Prejugez legitimes contre le Janſeniſme, avec une Hiſtoire abregée de cette erreur depuis le commencement des troubles, que Janſenius & M. Arnaud ont cauſez, juſques a leur pacification &c. a Cologne 1686, in 12.

Les plaintes des Proteſtans cruellement opprimez dans le Royaume de France. A Cologne 1686, in 12.

Lettre d'un homme desintereſſé écrite au ſujet de la Reponſe qu'on voit ici faite de la part de M. de la Chaiſe a la lettre que M. Spon lui a ecrite. a Cologne 1686, in 12.

Entretiens ſur la pluralité des mondes, par l'Auteur des Dialogues des Morts. a Paris 1686, in 12.

Conſiderations ſur le Traité Hiſtorique de l'Etabliſſement & des prerogatives de l'Egliſe de Rome & de ſes Evéques par M. Maimbourg. a Cologne 1686, in 12.

De l'utilité des voyages & de l'avantage que la recherche des Antiquitez procure aux Scavans. par M. Bandelot. a Paris 1686, in 12.

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Figure 2

Click here to download Figure Fig 2 CMYK DEF.tif

Figure 3

Click here to download Figure Fig 3 high resolution CMYK.jpg